REPORT

ON

SEWAGE DISPOSAL

AT THE

NATIONAL SOLDIERS' HOME

NEAR SANTA MONICA, CAL.

BY 1848 - 1912

JAMES DIX SCHUYLER

M. Am. Soc. C. E.
Consulting Hydraulic Engineer

WITH

NOTES ON THE SEPTIC PURIFICATION OF SEWAGE

BY

SAMUEL STORROW, A. B.

Assoc. M. Am. Soc. C. E.

LOS ANGELES:
PRESS OF B. R. BAUMGARDT & CO.

1900

CONTENTS.

INTRODUCTORY.

The use of sewage on the fields and gardens at the Soldiers' Home near Santa Monica prior to 1899 had been accomplished with little attention to sanitation and without any attempt to give it preliminary treatment to render it inoffensive, or innocuous, and unpleasant odors were frequently wafted on the breezes of midsummer to several farm dwellings situated in the lee of the irrigated fields. These odors became a serious nuisance and were complained of by the neighbors, one of whom threatened suit to enjoin the use of the sewage in that manner. This threat served to call the attention of the management to the subject, and negotiations were begun with the City of Santa Monica for the purpose of securing a means of disposal of the sewage into the ocean through the Santa Monica Sewerage System.

Prior to closing a contract for this method of disposal the author was requested to investigate the subject and report on all available methods of disposal of the sewage and the abatement of the nuisance complained of. The following report was prepared as the result of this investigation. This report has been submitted to the General Board of Managers of the Homes for Disabled Volunteer Soldiers, at Washington, and has received their approval, and the appropriation for constructing the septic tank recommended has been

made by Congress, and at the present writing is available for the work. The writer has been instructed to prepare plans and carry them into effect, and it is expected that the tank will be in operation before November 1st.

Its operation will be looked upon with no little interest by the Engineering profession, as, so far as known, it will be the first application of the principle of septic treatment of sewage on the Pacific Coast.

The publication of the report has been frequently urged by the friends of the writer familiar with it, but it did not appear to him as complete an expose of the biological processes involved as was desirable, and at his suggestion Samuel Storrow undertook the subjoined treatise on the subject, which, together with the report, is printed for private circulation, in the hope that it may prove useful to Engineers and laymen seeking a general summary of *fin de siecle* practice in sewage disposal.

JAS. D. SCHUYLER.

LOS ANGELES, CAL., August, 1900.

SOME NOTES

ON THE

SEPTIC PURIFICATION OF SEWAGE.

SAMUEL STORROW,
Assoc. M. Am. Soc. C. E.

LOS ANGELES, CAL.
1900.

SOME NOTES ON THE SEPTIC PURIFICATION OF SEWAGE.

The design of James D. Schuyler, Consulting Civil Engineer, of a system for the disposal of the sewage originating in the Soldiers' Home, near Santa Monica, includes the construction of a septic tank, so arranged as to be always filled with sewage. This idea is new in local practice and the interest shown in the method as evidenced by frequent personal inquiries, has led to this attempt to present more fully the biological side of the design and the beneficial results brought about by this septic tank.

These inquiries have been of two classes, from those whose interest is purely scientific, and from those who wish to know the applicability of the process to special cases. After examining thoroughly into the nature of the materials and processes employed, we will be able to outline the limits of the applicability of the biological methods of purification. The study and comparison of some of the local problems will then serve to exemplify the investigation.

II. SEWAGE.

Sewage is water seriously contaminated by the animal and vegetable wastes from the processes of human economy. The contained animal substances

are largely composed of fibrin, gelatin, chondrin, albumen, etc., all of which are unstable, complex compounds containing carbon, nitrogen, hydrogen and sulphur. These nitrogenous compounds speedily undergo decay by putrefaction, giving off foul odors whenever the supply of oxygen is deficient. The vegetable substances in sewage are mainly starch, cellulose, gummy matters and tannin. These decompose slowly, giving off few disagreeable odors.

The following table compiled from various sources* gives a fair idea of the constituents of ordinary sewage.

* "Purification of Sewage and Water," W. J. Dibdin.
"Sewage Disposal in the United States." Rafter & Baker.
"Report to London County Council." Clowes & Houston.

TABLE I.

SHOWING THE CONTENTS OF ORDINARY FRESH SEWAGE. PARTS PER 100,000.

Water.	Suspended Matter.			Dissolved Matter.			Total Impurities.			Ammonia.				Chlorine.	Nitrogen.	Nitrates.	Bacteria per Cubic Centimeter.
											Albumenoid.						
	Mineral.	Organic.	Total.	Mineral.	Organic.	Total.	Mineral.	Organic.	Total.	Free.	Soluble.	Insoluble.	Total.				
99,882	22.5	23.5	46	54.4	17.9	72.3	76.9	41.4	118.3	2.5	0.37	0.29	0.66	15.	9.4	Trace.	1,000,000 to 4,500,000

The mineral matter contained in the sewage is generally harmless. The whole problem consists in destroying the small amount of organic matter. The chemical composition of this organic matter, as a whole, is outlined above, and the chemical composition of the various animal and vegetable substances is shown in—

TABLE II.*

CHEMICAL COMPOSITION OF ORGANIC CONTENTS OF SEWAGE...PER CENT.

SUBSTANCES.	Nitrogen.	Hydrogen.	Oxygen.	Carbon.
Gelatin	18.3	6.6	25.	50.
Chondrin	14.4	7.1	29.4	49.
Albumin	16.	7.1	22.	53.
Cellulose		6.2	49.4	44.4
Starch		6.2	49.4	44.4
Fat		12.7	11.3	76.4

III. PUTREFACTION.

The usual putrefactive processes of Nature combine the organic substances present with a certain amount of oxygen. The nitrogenous matters are reconstructed with the giving off of ammonia or possibly of free nitrogen, oxides of nitrogen are formed, nitrous and nitric acids, carbonic acid, sulphuretted hydrogen, marsh gas, water, etc. Such are the chemical changes through which the organic contents of the sewage must

* Dibdin, Cit.

pass from its condition of dangerous and offensively putrifying nitrogenous organic compounds to inert and harmless nitrites and nitrates. This putrefactive process is materially assisted, if not wholly brought about, by the life action of certain small organisms called bacteria or microbes. These small organisms, by the process of their economy, utterly destroy all the organic compounds with which they come in contact, even to the extent of making a full meal of those of their late friends who may succumb to the infinitesimal struggle for the survival of the fittest. A full recognition of the essential part in all putrefaction played by these bacteria is a primary requisite for the successful dealing with the matter in hand.

The purification of sewage is the oxidation of the organic contents, chemically shown by the nitrogen appearing wholly as nitrates, biologically shown by the growth and change of the bacterial life through a cycle ending in the complete extinction of such life. Since the bacterial life is the cause of the chemical change and is itself dependent upon certain chemical and physical conditions, we have in our hands a simple control of the whole putrifactive process.

IV. CHEMICAL CONTROL OF PUTREFACTION.

Chemical purification of sewage effects one thing only, and that is the separation of the undissolved suspended matters from the liquid matters.* Certain experiments in the laboratory have gone beyond this point, but, whatever may be claimed to the contrary, there is no workable process by chemical precipitation yet invented which will yield a "tank effluent" even

* "Sewage Treatment and Sewage Disposal." W. S. Crump, Eng. and Bldg. Record XXVII, Eng. News XXIX.

approximately purified from its objectionable contaminations. The great claim for the value of many chemical processes of purification is the consequent saving of the manurial values in the sewage. Sewage does contain ingredients of considerable manurial value, but they are as the needle in the haystack. It has hitherto always cost more to prepare the manure for market than it will sell for when prepared.

When the local conditions in any case are such that the manurial contents of the sewage can be made to yield, or assist in yielding,* some return for its treatment, this should by all means be done. But it must be borne in mind that the primary object is to dispose of the sewage thoroughly and without nuisance.

There are many cases where the rapid precipitation of the solid suspended matter is advisable, and in a few of these cases chemical precipitation may be indicated, but even here bacterial processes are rapidly proving a superior adaptability. In a few cases chemical treatment is indicated on account of its encouraging or retarding influence on the bacterial life processes.

V. CHEMICAL ANTISEPTIC TREATMENT.

One must carefully distinguish between chemical processes having for an object the oxidation of the organic contents of the sewage and chemical processes looking to the prevention of putrefaction by antiseptic means. The addition of chemicals to assist the bacterial life is generally along the line of attempting to add to the amount of oxygen in the water, and thus is merely a part of a bacterial system of purification. The antiseptic treatment is directly opposed to the main object sought to be accomplished. We have already seen that the oxidation of the contained organic mat-

* See papers in Jour. Roy. Ag. Soc. of England.

ter is the ultimate end sought, so that any method of preservation or prevention of decay by antiseptics must be worse than useless, as it destrovs that bacterial life upon the active life processes of which we are dependent.

Deodorization, as distinct from disinfection, is sometimes properly employed when it is desired to obtain temporary relief from offensive odors. The result of all experience up to date seems to show that bacterial processes alone can be depended upon to solve all our vexed questions of sewage disposal without nuisance, and that chemistry will merely serve as a check of the amount and rate of the work being done.

VI. BACTERIAL TREATMENT OF SEWAGE.

It is known that the process known as nitrification of the complex nitrogenous organic compounds existing in sewage is brought about by two definite classes of organisms,* each producing a distinct stage in the process, and each being so distinct in its life history as to admit of substantially separating these two stages of the putrefactive process. The life processes of one of these classes of organisms liquefy the suspended organic imprities, and the life of the other yields nitrates. By a judicious control over the conditions affecting the growth and multiplication of one or the other of these organisms we can readily stimulate or retard either part of the process.

The aerobic organisms, when oxygen is freely present, destroy the organic matters contained in sewage without the accompaniment of offensive products. The anaerobic organisms multiply and act where there is no air and yield inoffensive products.

These two classes of organisms are always present

* Investigations Rothamsted Station, Robt. Warington, Bulletin No. 8.

in crude sewage. They are bacilli and so minute in size that it is difficult to describe them in popular terms. In "Applied Bacteriology," by Permain & Moore, we are told that if we could view an average man under a degree of magnification equal to the higher powers used in the microscopic study of bacteria, he would appear to be about four miles high. So rapid is the multiplication of bacteria under favorable conditions that in one week the number of the descendants from one bacterium would be expressed by a number of fifty-one digits. Forty thousand million bacteria weigh one grain, and yet in three days the combined weight of the descendants of a single microbe would weigh 7,366 tons. Five hundred million microbes have a bulk equal to the head of a pin, and yet in five days the descendants of one bacillus will aggregate the volume of the entire ocean. It is needless to say that these figures are the theoretical increase without death or disaster. The lack of food and the presence of unfavorable physical conditions prevent unmanageable multiplications of this description. Enough has been said to show the enormous force that the engineer has at his disposal when he enlists the friendly offices of the bacteria.

VII. THE PRINCIPLE OF THE CONTROL OF PUTREFACTION BY CONTROL OF BACTERIAL CONTENTS.

In a report by Dr. A. C. Houston, M. B., D. Sc., written August 9th, 1898, and since then materially endorsed, we read :—

> "Sewage already contains all the organisms which are necessary for its decomposition and final purification. In order to discover a method of biological treatment all that has to be done is to discover the best and most practical way of allowing the natural purification

by the action of the bacteria to take place without nuisance or danger.

"In brief, the so-called biological treatment of sewage is neither more nor less than the attempt to imitate nature's own methods of effecting the decomposition and finally the purification of the effete matter of the animal and vegetable kingdom.

"Putrefaction has been called putrid fermentation, but putrefaction is rather to be looked upon as a fermentation which is putrid or otherwise, according to the conditions under which it is conducted and the degree of its completeness.

"The products of decomposition by so-called putrefaction are of the most varied kind, and there is no doubt that putrefaction is brought about, not by a single germ, but by a large number of different bacteria, some aerobic, others anaerobic. Each one of these germs may produce intermediary products of widely different character, but all of them, perhaps, tend in the direction of finally resolving highly complex substances to their simplest component parts.

"Now the organic matters found in sewage are partly in suspension and partly in solution, and sewage contains in itself the necessary living germs for the destruction of both these forms of organic matter. The aim and object of the biological treatment of sewage is to render soluble by microbial agencies the solid matters.* In the final process of purification, these substances should undergo oxidation induced by the life processes of nitrifying organisms, and an effluent should be produced, which is free from putrescible matter and contains only inorganic or mineral substances.

"The mere solution of the great mass of the suspended matters by bacterial agencies, which is, perhaps, common to all the different processes at present under trial, is a sufficient vindication of the enormous advantage to be gained by the biological treatment of sewage. One point which has been rather lost sight of is that there is probably no bacterial process in practical operation at the present time which is not eminently successful in that it places the sewage in a most favorable state for its final purification by land irrigation.

"The presence of bacteria in enormous numbers in an effluent does not perhaps necessarily imply that the effluent is of a degraded character and highly putresci-

* This is accomplished in the Septic Tank, as explained in IX.

ble; it may only mean that the liquid has passed through a previous stage of putrefaction, preparatory to its purification, in which case the danger so far as nuisance is concerned may be regarded as potential and not actual."

When the sewage is first formed it contains a great variety of bacterial life. As it passes onward through the plumbing arrangements and into the sewers the putrefactive processes become active, and it is the object of good sewers to remove the sewage so quickly that the rapidly generated noisome odors will not be generated until the sewage has passed too far away to offend our eyes or noses. The construction of these sewers is a matter of hydraulic engineering not germane to our subject. The contractor who builds the sewers and often the engineer who designs the sewerage system knows little or nothing about the life process that may go on in sewage. He is concerned only that his pipes and sewers shall carry their burden and discharge it from the lower end. How needless it is to say that a better design and better construction can be made by an engineer who fully realizes that his problem of disposing of the sewage really means more than the mere transportation of the offensive matters.

In the great majority of sewerage systems the whole system is looked upon as a nuisance to be buried underground and lost to sight and mind as soon as possible. No thought is given to the mighty forces at work, which, if properly controlled might readily allow of a very material purification of the sewage as it flows onward to the outlet, and all this without offense or material expense, thus often doing away with the need of a large and expensive outfall sewer at the same time that the sewage is discharged in a condition of sufficient purity to admit of its profitable use.

The contents of the raw sewage is well shown in Table I. It will be noticed that each of the objectionable organic impurities, the complete oxidation of

which is the object sought to be accomplished, already contains a considerable quantity of oxygen. There is also present, dissolved in the water, a considerable amount of oxygen. Since the complete destruction of the organic contents of the sewage is merely oxidation or slow combustion, it is pertinent to inquire what proportion of the needed oxygen is already present in the sewage. The amount of oxygen required to oxidize the substances shown in Table II as the principal organic contents of sewage is shown in Table III.

TABLE III.*

POUNDS OF OXYGEN REQUIRED TO OXIDIZE 100 POUNDS OF CERTAIN SUBSTANCES.

SUBSTANCE.	Oxygen Required by the				Oxygen Present.	Amount of Oxygen to be Added.
	Nitrogen.	Hydrogen.	Carbon.	Total.		
Gelatin	52.3	52.8	113.3	248.4	25.0	223.3
Chondrin	41.1	56.8	131.0	229.0	29.4	119.6
Albumen	45.7	56.8	141.4	253.9	22.0	231.9
Cellulose		49.6	118.4	168.0	49.4	118.6
Starch		49.6	118.4	168.0	49.4	118.6
Fat		101.6	202.5	304.0	11.3	292.8

Some of this oxygen is already present in the water of the sewage. At the temperature of 62 degrees F., and at the normal pressure of the atmosphere at sea level, air contains 21 per cent of oxygen and still pure

* Dibdin, Cit.

water contains 6-10 per cent of oxygen by volume. As the essentially pure water passes from the water supply into the sewers it becomes contaminated with organic matter, and the multiplying aerobic bacteria at once begin to draw upon the oxygen. So long as a supply of oxygen remains distributed throughout the liquid the aerobic bacilli predominate over the anaerobic forms and the putrefaction goes on without the accompaniment of offensive smell. If the withdrawal and use of the oxygen could be offset by the addition of a new supply increasing up to the amount demanded by the rapid growth and increase of the aerobic bacilli, the growth of the anaerobic forms might be permanently held in abeyance and the sewage wholly purified without offense.

This idea is attempted wherever sewerage systems discharge into large bodies of water, and depend upon extreme dilution to render the sewage unobjectionable; but this method is generally unsuccessful because the amount of oxygen already contained in the sewage and diluted waters, supplemented by additional absorption as the first is used, is not enough* to supply the demand. A very material purifying action undoubtedly takes place. It may be that the purification is ultimately essentially perfect.

ATTEMPTS TO RENEW THE OXYGEN.—The amount of oxygen withdrawn by the life processes of the bacteria can be replaced in various ways. Permanganate of potassium serves as a deodorizer, and by decomposition as a source of supply of oxygen. The action of the oxygen from permanganate of potassium is peculiarly selective, acting first on those matters which are

* Dibdin, Cit., pp. 124-129.
Rafter & Baker, Cit., pp. 9, 23, 73.
22nd An. Rept. Mass. State Bd. Health, pp. 525-543.
Jour. Frank. Inst., Nov. 1891.
Trans. Am. Soc., C. E. XXIV, 21.

in an advanced stage of decomposition. In the small quantities possible to employ in sewage purification, it is not an antiseptic.

OXYGEN FROM AIR.—Since the oxygen originally in the water that has become sewage came from the air it has often been tried to utilize the air as the source of re-supply. Complete processes* of purification are dependent upon this idea, the air being driven into the sewage by the aid of pumps. In this way oxygen is undoubtedly added, but the violent agitation of the sewage is detrimental to the action of the bacteria for whose benefit the oxygen is being added; and the maintenance of a system of air pumps with men to care for them, is a matter of considerable expense.

OXYGEN BY INTERMITTENT FILTRATION. — The most successful method of adding the needful oxygen is by the method of intermittent filtration by which, at intervals, a certain amount of sewage is run into a filter bed so prepared that the sewage sinks down and through the filtering medium and is discharged, allowing the surface and interstices to be exposed to the air for the absorption of oxygen for a certain length of time, before the filter receives its second load of sewage. This method, while simple in its apparent action, is so important as to deserve a careful analysis. It is not simply a method of filtration, but of the combined straining and filtering out of the suspended and undissolved organic impurities and the destruction within the filtering medium of both the undissolved and dissolved organic impurities. It is capable of discharging a filtrate unobjectionable to sight, smell or taste, except for its containing certain mineral nitrates. This result is brought about wholly by bacterial action. The so-called filter beds are really bacterial beds, and as such should be described.

* Geo. E. Waring's process, as installed by D. A. Tompkins & Co.

VIII. BACTERIA BEDS. ACTION, CONTROL AND CAPACITY.

Among the earlier attempts in purifying sewage was that of filtration, or the straining of the sewage through beds of sand and gravel so fine as to prevent the passage of the suspended matters. The effluent was soon found* to have also parted with much of its dissolved organic matter. Such a result was not well understood at first, but we now know that it is due to the action of the bacteria contained in the filtering medium. So important is the bacterial action and so much more does it accomplish than the merely mechanical action of filtration that the whole process is now designed primarily for the encouragement of the growth and action of the bacteria; the idea of filtering being essentially a secondary consideration.

The most energetic nitrifying bacterial action taking place as a result of the life processes of the aerobic bacteria in the presence of oxygen, it has been found best to so design the system that intermittent charges of sewage are passed into the surface of the beds and sinking slowly downwards and draining away from below are followed by the entrance of air. Thus the contained bacteria are well nourished and stimulated to their utmost activity by alternate doses of rich food and oxygen. Earth, sand and gravel are the materials most commonly employed to make the bacterial beds, and these are laid down in layers in previously prepared excavations, so connected with the sewage supply that the action of filling first one bed and then another is automatic.

The earthy filling of the beds acts as a breeding ground for the bacteria, which develop in great num-

---

* Reports Mass. State Board of Health, Lawrence experiments.

Rafter & Baker, Cit., p. 286.

bers and of such varieties as will thoroughly dispose of the raw sewage, destroying the dissolved organic impurities at once and rapidly acting upon the suspended matters.

The degree of purification from these bacterial beds is highly satisfactory.* The amount of sewage that can be applied per acre is far greater than can possibly be utilized by the plant life growing on the filters. In the best English practice 10,000 gallons per acre per day (or a little less than one-half of an inch in depth) is purified by irrigation. In Paris 30,000† gallons per acre per day (or 1⅛ inches in depth of water) is discharged into the fields per day. Here in California we consider an annual supply of water equal to 24 inches in depth per year (applied in six months) an ample supply, or less than one-eighth of an inch per day. This is 3,600 gallons per acre per day. There are cases on record of successful farming in San Diego County for several successive years with quantities of water equal to about one-fourth of this. All of which goes to show that in the purification of sewage by broad irrigation the action of the growing crop is an unimportant factor, and if we are merely trying to purify the greatest amount of sewage with the least expenditure of time and land we can accomplish our desired result more satisfactorilv on land prepared for that specific purpose.

Sewage that has been passed through properly constructed bacteria beds is so purified and relieved of its objectionable organic contents that it is probably much purer than the ordinary drinking waters furnished in cities taking their supply from rivers. In the Lawrence experiments bacterial beds of fine sand were

---

* For a statement of the case of Berlin, Germany, see "Sewage Farms of Berlin." H. A. Roechling, Proc. Inst., C. E., CIX, 3.

† Eng. News, XXXIX, 2.

used only five feet thick. On these sewage was poured at the rate of 100,000 gallons per acre per day. After these had been in use a long enough time to have assumed a stable condition, the effluent from tank No. 2 was frequently used for drinking, without any noticeable effect. Seven wells in constant use were chosen to represent an average, and seven purified effluents from seven different tanks were chosen for comparison. The average result is shown in—

TABLE IV.

COMPARISON OF EFFLUENT AND WELL WATER, LAWRENCE, MASS. PARTS PER 100,000.

Average Effluent from	Ammonia.			Chlorine.	Nitrogen.		Bacteria per cubic Centimeter.
	Free.	Albuminoid.	Total.		Nitrites.	Nitrates.	
Tanks 1, 13, 6, 6, 4, 2, 7.......	.0060	.0113	.0173	4.74	1.19	.0002	238
Seven wells.....	.0256	.0086	.0342	5.84	2.02	.0011	801

This table does not show that all effluent from all bacteria beds is sufficiently purified to be safely used for drinking water. To quote the words of Hiram F. Mills, M. Am. Soc. C. E.:—

"Judging by the chemical analysis, there is nothing in the effluents known, or even suspected by chemists, to be harmful.

"Although nearly all of the bacteria that were in the sewage did not live to pass through the filters, there have been found in the effluents from filters of coarse sand more bacteria than are found in some public drinking supplies, and some of these evidently came from the sewage; and, until we learn that disease-producing bacteria are not among those that come through, we

> must assume that they may be among them; and although reduced in numbers to such an extent that they may do no harm, we yet know that bacteria in general increase with enormous rapidity when under favorable conditions, and we do not yet know enough to allow us to assume that the very small number of one or two in a thousand of the number in the sewage that come through may not increase in the human body or under other conditions to such numbers as to be harmful.
>
> "From this cause we are not able to assume that the effluent from coarse-sand filters five feet in depth is suitable for drinking water."

This extraordinary degree of purification is brought about by the life action of the bacteria, and the object of the engineer is to provide the best breeding and feeding ground for these minute organisms. The action of the bacteria on the sewage is two-fold, and it is possible to so essentially separate these two stages that the modern sanitary engineer can design the purification system in two distinct parts. By reference to Table I it will be seen that of the contained organic matter 43 per cent is in the form of undissolved solids, and 57 per cent is in the form of solids that have been dissolved. Since the desired breaking down of the complex organic compounds is to be a chemical action brought about by the digestive action of exceedingly minute organisms, the first step is to prepare their food in the condition of the finest division possible. This is accomplished by those bacteria having a liquefying or hydrolytic action. It is probable that this liquefying action is largely brought about by certain products of the micro-organisms called "enzymes," which, though not living, are the product of the anaerobic forms of animal and vegetable life. By the production of these enzymes the sphere of action of the liquefying bacteria is considerably widened. This liquefying action being caused mainly by the action of the anaerobic bacteria,

the first work is to stimulate the growth of the anaerobic organisms.

When sewage is first formed, by the origin of the domestic wastes, the first putrefactive action must be aerobic, on account of the oxygen dissolved in the fluids and the surrounding air. The presence of this oxygen results in the production of small quantities of nitrates. This initial oxygen, and with it the vivified aerobic forms of organisms are soon exhausted. The action of the aerobic forms is checked even if the bacteria are not wholly destroyed. The anaerobic forms multiply and carry on the work. By their aid the solids are broken down and become liquefied and dissolved in the sewage. The process to this point includes the formation of ammonia, nitrous and nitric acids, free nitrogen, methane, hydrogen, carbonic acid, marsh gas, etc. These gases are inflammable, and can be burned or discharged into the air without nuisance. After the complete liquefying of the organic contents of the sewage it is time to again call in the aid of the aerobic bacteria to nitrify the dissolved materials in the presence of a large amount of oxygen.

It is feasible to somewhat combine all these processes and indeed it is somewhat probable that two or more kinds of bacteria acting together can effect decomposition which neither of them can do separately and that in no case can we expect to so differentiate as to restrict the action to one species.

The most that can be hoped for is to introduce physical conditions that will assist the desirable forms and retard the growth of others.

In large cities the sewage is from one to two days or more old when it arrives at the works. At this stage, after being in dark sewers so filled with the exhalations of the decomposing material as to be essentially devoid of oxygen, the sewage is already rapidly approaching the condition of a complete liquid. If

this sewage is discharged onto a considerable area of prepared bacteria beds the bacteria there present will rapidly destroy all its organic contents, and that without offense to sight or smell. After such a hearty meal some of these bacteria require rest and oxygen, after which they will not only be ready for another dose of sewage, but will also so increase in number and ability as to effectually purify 200,000 gallons of sewage on each acre per day. By a careful study of the action of these purifications, it was soon found that the action was controlled by purely biological processes. The mechanical filtering action of the soil is actually detrimental, for it causes the coarse particles of sewage to remain on the surface and act as an impervious layer interfering with the free entrance of the sewage into the soil. It has also been found largely by experiment what size and kind of earthy material, and what times for charging and discharging will gain the best results. The whole process has been experimentally worked out, and every step has been checked and re-checked by repeated chemical and biological analyses.

As a final result we know that success in thorough destruction of the organic impurities in sewage is dependent upon several conditions which may be summarized as—

1. A range of temperature from not lower than 20-25 deg. Fahr. for the coldest winter months up to the limit known.

2. The solution of sewage must not be too strong.

3. The solution must be slightly, but not more than slightly, alkaline.

4. The solution must be in contact with the bacteria beds at least three hours. A longer time may give a greater, and a lesser time is sure to give a lesser degree of purification.

5. The bacteria bed must be well aerated after each application of sewage.

In practice it was found that the most efficient action of the bacteria filter beds was within a foot or two of their surface, but that if coarser materials were used and the sewage not allowed to escape until it had been held in contact with the filtering medium and bacteria for some hours an equal degree of purification was obtained and the action proceeded throughout the full depth of the filter.

Since the purification is by bacterial action, and since we can approximately control the growth and activity of the various species, we are prepared to control the rate and amount of putrefaction and exhalation of offensive odors, and can carry the destruction of the organic putrescible material to any desired degree of completeness. Air with its contained oxygen admitted into the bacteria beds in alternate doses with liquid sewage, stimulates the growth of aerobic bacteria, and retards the action and development of anaerobic forms. Keeping out oxygen stimulates the anaerobic forms at the expense of the aerobic. The complete putrefaction, if it be done without offense, needs a careful adjustment of the action of the two forms. We wish to first liquefy the suspended organic matters with the aid of the anaerobic forms. If we push the action of the anaerobic forms too far, we will get a solution highly toxic to aerobic organisms, and one very slow to nitrify. If we stop the hydrolytic action at just the right point the dissolved organic impurities have become an ideal food for the aerobic organisms. The attempt has been made to develop the two forms side by side or to obtain bacteria that alone or conjointly with others will complete the putrefaction without objectionable exhalations, but so far without much success, except by slower

action than when sharp differentiation is attempted between the aerobic and anaerobic forms.

By carefully dividing the process of putrefaction into its two parts, the liquefying or anaerobic and the nitrifying or aerobic, and providing the proper facilities for the assisting of these processes we at once raise the purification of sewage to the level of a science.

The aerobic forms of bacteria effect the real purification by destroying the dissolved organic material. Food, oxygen, and rest, delivered alternately to a good breeding ground, is the essential of success, and so successful is this process today that it is easy to sufficiently purify 2,000,000 gallons* per acre of prepared filter beds each twenty-four hours. This is a depth over all parts of the filter bed of more than three feet per day, or 1120 feet per year, or, according to the usual American practice, one acre of prepared filter bed will purify the sewage originated by 17,500 people.

In order that this rapid rate of working shall be kept up, it is necessary that the bacteria in the filter bed should be of no other form and have no other duty to perform than that of destroying dissolved organic impurities, and that the supplies of oxygen and food shall be rightly proportioned throughout all parts of the bed.

The filter beds are, in effect, tanks of a size varying from ten feet square and three feet deep to one hundred feet square and ten feet deep. In one case at Crossness, England, a tank is in use having an area of one acre (209 feet square) and a depth of only three feet of filtering material. Whatever size tank is used, it is filled with some coarse material, the particles of which vary from the size of peas to that of eggs. Experience has proved that particles of this size admit of more rapidly filling and emptying the bed and that the enter-

* Experience at Crossness, Eng.

ing air more thoroughly penetrates to every part and more easily reaches the colonies of bacteria growing on the surface of the particles; so that, the whole of the bed being thoroughly drained and thoroughly aerated each time, no opportunity is afforded for the development of the anaerobic forms, and the whole tank is utilized by the nitrifying aerobic forms. Experience has further shown that coke is the most effective material for the bed, of a size that will pass through a ring two and one-half inches in diameter but be caught on a ring of one-quarter-inch diameter. Burned clay, coal, and even cracked stones have given most excellent results. Sand, earth, loam, cinders and other fine materials give a lesser rate for the same area of bed. It is supposed that this lesser rate is due to the difficulty in thoroughly draining a fine bed, the water being held as in a sponge, and there is consequent failure of complete aeration and the development of active aerobic action throughout the whole bed, while the anaerobic forms are allowed a too energetic action.

The details controlling the admission and discharge of the sewage are simple and well tried. These, as well as the questions pertaining to the exact size and shape and material, the location, and other constructive questions, are directly pertinent to the profession of the engineer and must be varied as the circumstances of each case may require, and the engineer alone, with his knowledge of the stresses, physical and chemical, that each part must withstand, can so design and construct the works that premature disaster will not overtake them.

IX. SEPTIC TANKS, ACTION AND CAPACITY.

With this thorough knowledge of the forces at work in the purification of sewage, we are prepared to understand at once the need and action of the Septic Tank,

the presence of which in Mr. Schuyler's design for the Soldiers' Home has called out this discussion.

The aerobic forms of bacteria eat and destroy only the dissolved organic impurities. It is, therefore, logical that into a bacterial bed suitable for the growth of only aerobic forms we should introduce only such sewage as has had its originally suspended organic contents changed wholly into dissolved organic matter. This change is brought about by anaerobic bacteria, thriving only in the absence of oxygen. The Septic Tank is for the growth and action of these forms. In essential design it is merely a closed tank, into which the sewage flows so slowly as to produce no eddies. The scum and grease rise to the surface of the sewage and form an essentially air-tight cover. The suspended mineral matter sinks to the bottom. The oxygen originally contained in the sewage is rapidly exhausted and the anaerobic forms of bacteria multiply and complete their cycle of life, rapidly liquefying all the suspended organic matter. A very considerable amount of gas is given off, largely marsh gas, but it is without offensive smell, except for a short time when the tank is first brought into use and the aerobic forms of bacteria are endeavoring to work with a deficient supply of oxygen. When the tank has settled down to steady work on a substantially uniform sewage, the gases eliminated are unoffensive and may be discharged freely into the air or burned, the mixture being highly inflammable, as the opportunity offers.

The sewage, being admitted quietly below the surface of the tank at one end, flows quietly out from a point below the surface at the other end, and the tank is so proportioned that the time of passage from entrance to exit will be about twenty-four hours. Such suitable contrivances are introduced into the design of the tank as will tend to make the movement of the

sewage very uniform and will prevent the access of air. It is not proved that an air-tight roof is essential for the safe-guarding of the anaerobic bacteria, however desirable it may be from an æsthetic standpoint. It can do no harm and its action cannot but be beneficial in a windy country or where the action of the sun is very intense.

The discharge from the Septic Tank is in no sense purified; its contained organic material is merelv wholly dissolved and a fit food for aerobic bacteria. It may be fed to the aerobic forms by

1. Dilution in streams or the ocean.
2. Broad irrigation.
3. Intermittent filtration through bacteria beds.

We have already considered the action of the bacteria in disposing of the dissolved organic contents. The action and result is the same, however and wherever brought about.

In brief, dilution is only allowable where the water into which the sewage is discharged is never used as a public water supply or for pleasure purposes within the radius of complete destruction of the organic contents. Broad irrigation with crude sewage requires a very large acreage of land, and is adapted onlv to certain very special cases, for it is proved beyond a doubt that crude sewage can so contaminate growing crops as to make them unsafe for human consumption and in a lesser degree so contaminate the flesh or milk of graminivorous animals, although it is probable that the processes of the putrefying bacteria destroy the pathogenic germs contained in the sewage, and that broad irrigation will ultimately destroy all pathogenic germs, if thoroughly and carefully carried out. We also know that thorough destruction of sewage by farming it into the soil requires a greater amount of work and more intelligent care than is commonly met

with. A few cases have been proved where vegetables contaminated by sewage have been the cause of disease. Intermittent filtration through bacteria beds is an absolute destruction of all dangerous sewage. When either irrigation or filtration is preceded by a thorough treatment in a septic tank the sewage may be used for irrigation with a perfect feeling of safety as regards health and a perfect immunity from smell or nuisance, but is is not safe to discharge the effluent from a septic tank into any body of water afterwards used as a source of supply for public drinking water, except it be first further purified as by coke bacteria beds. In reference to this there is no higher quotable authority than Prof. Frank Clowes, Chief Chemist to the London County Council, London, England, who says:—

"It should be explained that the experiments on intermittent treatment in the coke beds have been carried out by filling the coke-beds with sewage until the coke is just submerged, then allowing the sewage to remain in contact with the coke for several hours, and finally draining the liquid away completely. The coke is then allowed to remain for some time in contact with the air, which fills the interstices of the coke-bed when the liquid has flowed away. This series of processes is repeated at regular intervals.

"It may be stated that the general results obtained from about ten months' experiments of the coke-bed treatment point to the following conclusions:—

"SIZE OF COKE.

"The use of ordinary gas coke, in pieces about the size of walnuts, seems to be attended with the following advantages, as compared with the use of smaller coke. The larger coke enables the bed to hold a larger volume of sewage. The beds now in use had an original capacity for sewage which was nearly equal to the volume of the coke which they contained, in place of only 20 or 30 per cent of that volume, as is shown by beds containing smaller coke. The use of the large coke also allows the bed to be more rapidly filled and emptied, and to be more completely emptied and aerated.

"DEPTH OF COKE.

"A bed 13 feet in depth has now been working satis-

factorily since April 16th, 1899, and has given a purification approximately equal to that effected by the four-foot bed.

"CHEMICAL PURIFICATION EFFECTED BY A SINGLE TREATMENT.

"The coke-beds have removed the whole of the suspended matter, or sludge, from the crude sewage; and they have yielded an effluent which occasionally shows a slight turbidity, apparently due in ordinary flow mainly to the presence of bacteria, which is increased in storm flow by fine clay and mud.

"Not only has the suspended matter been removed, but the removal of the dissolved oxidisible and putrescible matters of the raw sewage has been secured to the average extent of 52.7 per cent by the passage through a single four-foot coke-bed. The effluent thus produced remains free from objectionable odor when it is kept in open or in closed vessels, provided the bacteria present in it are not removed or killed by special subsequent treatment.

"PERMANENCY OF COKE-BEDS.

"Since the coke-beds have become regular in their action, neither the effluent nor the coke itself has become foul.

"The capacity of the four-foot coke-bed, has during the period in review been reduced from 50 to 33 per cent of the whole volume of the bed, and this reduction of capacity appears to be mainly due to fragments of straw and chaff, apparently derived from horse-dung, and to woody fibre derived from the wear of wood pavements. (Note. This sedimentation of the coke-beds has now been prevented by a simple but satisfactory device.)

"AMOUNT OF SEWAGE WHICH CAN BE TREATED DAILY BY A SUPERFICIAL UNIT OF THE COKE-BED.

"The volume of sewage which can be passed through the coke-bed per unit of superficial area has not yet attained its maximum, since the depth of the coke-beds is being further increased. It originally amounted to 555,000 gallons per acre per day for the four-foot coke bed, and to 832,500 gallons per acre per day for the six-foot coke bed. This represents in each case one filling per day; but as has already been stated, two fillings have been made successfully since February, 1898, and this corresponds to 1,665,000 gallons per acre per day for the six-foot coke-bed.

"The maximum possible rate of treatment by each coke-bed is possibly not yet reached.

"The above daily rate of treatment will naturally be augmented as the depth of the coke-bed is increased, and if the satisfactory working of the 13-foot bed is maintained, it will treat a volume of raw sewage equal to at least three-and-a-half million gallons per day. (Note. This 13-foot bed is now in active operation at the rate of 4,200,000 gallons per acre per day.)

"EFFECT OF EFFLUENT ON FISH.

"Fish die at once when they are placed in the effluent produced by chemical precipitation. Not only gold-fish, but roach, dace, and perch have lived for months in the first effluent from the coke-beds, and they apparently would live and thrive in this liquid for an indefinite time.

"BACTERIALOGICAL CHARACTER OF THE EFFLUENT.

"The results obtained by the bacteriological examination of the effluent by Dr. Houston thus far seem to indicate that the coke treatment does not by any means remove the bacteria from the crude sewage, and indeed does not materially reduce the number. It shows that the presence of many of the bacteria in the effluent is possibly unobjectionable, and is probably necessary for the purpose of completing the purification of the effluent.

"GENERAL CONCLUSIONS.

"The liquid discharged from the outfall will be sweet and entirely free from smell, it will carry within itself the bacteria necessary for completing its own purification in contact with aerated river water, and under no conditions can it therefore become foul after it has mingled with the stream. The effluent will in no way interfere with fish-life in the stream."

X. THE MEASURE OF THE PURIFYING ACTION.

From Table I we find that 100,000 parts of sewage contain 41.4 parts of organic matter. It is this small amount of organic matter, less than one pound in a ton, about one pint in fifty barrels, that causes all the trouble, and the thorough destruction of this small amount is our sole object. This organic material is

not so dangerous in itself as it is dangerous because the home and source of nourishment of myriads of bacteria which are in themselves, or by their secretions and waste discharges, or by their own decay, highly poisonous when planted in the human system. We have seen that the process of putrefaction is a process of graduated purification, and that, in the final product, the sewage is called purified because it is free from organic material. The purifying bacteria were seen to be of two forms, each multiplying and going through its special cycle of work, the one dependent on the other, but not working exactly conjointly, as the material making the most available food for the liquefying or anaerobic forms is not yet ready for the nitrifying or aerobic forms. We have further seen that the giving off of foul smells is due to the action of the aerobic forms working in a deficient supply of oxygen. By this knowledge of this complete cycle we have a measure of the action. By taking a sample of the crude or partially purified sewage and subjecting it to an analysis of the forms of its contained bacteria, by a simple determination of what proportion of its originally suspended organic matter has become dissolved and oxidized, by sight and by smell, we have a means of testing how far has been the progress toward complete purification. Starting with a material essentially free from anaerobic bacteria, we watch the rapid growth of those forms and the decrease of the aerobic forms as the dissolved oxygen is exhausted. Then comes the death of the liquefying anaerobic forms and the rapid increase of the nitrifying aerobic organisms and finally the completion of the work and the death of all forms.

Table No. I shows that in crude sewage that has advanced far enough in the sewerage system to reach the site of the purifying plant there are from one to four million bacteria per cubic centimeter. One cubic

centimeter is a bulk about equal to one inch of an ordinary pencil. When the putrefaction of sewage is active this small bulk contains many million bacteria, and it would be clearly impossible to count its inhabitants even if we could see them or prevent an increase in their numbers while we were counting. The method of counting is to take one cubic centimeter of the sewage under examination and dilute it with pure water to measure 1,000 or 10,000, or even 100,000 cubic centimeters, and then, taking a small quantity of this dilution mix it with gelatine and pour it onto a glass plate. The gelatine hardens, holding the bacteria fast, and the dilution of the sample of sewage has been so arranged that there are but a few or a few hundred bacteria on the plate, each separated from his neighbor and held fast in a mass of gelatine. Each of the bacteria grows and makes a marking on the gelatine peculior to his kind and species, giving us ample opportunity to count and study them. The amount of the original sample of sewage being one cubic centimeter and the amount of dilution of the water that has been added being known and the number of bacterial developments or colonies on the gelatine plate being counted it is easy to compute how many bacteria were in the sewage from which the sample was taken.

The effect upon the gelatine varies with the different species, and nearly all can be recognized by this means. The number and varieties that have been recognized in purifying sewage is very great, but the presence and number or the absence of certain varieties is a marked characteristic of certain stages of the process.

But as these biological methods of testing the progress of the purification require a knowledge and skill and the possession of facilities not commonly available, other and simpler methods of control are afforded by chemical tests. The simplest of these is to make a

determination of the amount of oxygen necessary to oxidize a given amount of the crude sewage and another determination of how much oxygen is needed to any partially purified sample. The ratio is the percentage of purification already completed. This determination is easily made by measuring the amount of oxygen absorbed by any given sample. By applying this idea in detail, we can determine—

First: The amount of organic matter in the sewage susceptible to oxidizing at any stage of the process of purification.

Second: The quantity of matter, organic or mineral, held in suspension or dissolved.

Third: The quantity of nitrites and nitrates.

The object of the whole process being the changing of the oxidizable organic compounds into mineral nitrites and nitrates, these points mark the several steps in the process, and an accurate determination of them enables the engineer to gauge the efficiency of his work, to remedy or ward off trouble, and to work the purifying plant at its best and most economical capacity.

XI. EXAMPLES.

So many small towns have begun to re-arrange their systems of sewage disposal in accord with modern biological ideas that no complete list can be given. In some cases entirely new systems have been built, especially by the smaller towns and for the sewage from isolated clusters of buildings, but more often the change has been because of dissatisfaction with the results of, and a desire to change, some existing system, as was the case at the Soldiers' Home primarily under consideration. At London, England, the average daily sewage discharge is 250,000,000 gallons, with a maximum of 400,000,000 gallons per twenty-

four hours, and this amount is steadily increasing. Exceedingly costly chemical tanks and processes have been tried and found wanting. At the present time biological tanks and coarse bacteria beds are being built by merely filling the old precipitating tanks with coke. In some cases the sewage is passed through a second bacteria bed immediately after leaving the first. Sometimes it is discharged directly into the river. In the case of London, so great is the area served, the sewage is generally quite thoroughly liquefied when it reaches the works, so that the sewers themselves serve as a septic tank. The principal variation from the ordinary in London has been making the filter beds thirteen feet thick, which are now handling sewage at the rate of over 4,000,000 gallons per acre per day, with most excellent results.

On the grounds of a golf club near Chicago a very severe test was made of the septic system. A small club house yielding only 850 gallons per day was fitted with one tank twelve feet square by three feet deep, and the effluent afterwards passed through a bed of coke twelve feet square. Before the season was over the crowds at the club house had so increased that the daily sewage was more than 6,000 gallons per day. At this point the system of purification was overworked and broke down. But a short rest and a few minor changes restored its efficiency, and the only change that has been made in the design is to increase the size of the tank so that the septic tank will have a capacity equal to the sewage originated in twenty-four hours, and the filter tank will not receive sewage at a rate greater than 500,000 gallon per acre per day.

As showing what has recently been done the following table has been prepared:

TABLE V. SHOWING SIZE AND CAPACITY OF VARIOUS SEPTIC PURIFICATION WORKS.

PLACE.	Daily Flow, Gallons.	Septic Tank.			Bacteria Beds.					Reference.	
		Number.	Size.	Capacity.	Number.	Size.	Gallons per Acre per Day.	Times Filled per Day.	Material.	Vol.	Page.
Overbrook, N. J.	80,000	1 1	50x18x10 58x—x1.5	65,000	1 1 1	80x30x3 70x30x3 58x—x1.5		3	Sand on Coke	Eng. Rec.,	40,669
Aldershot, Eng.	1,000,000	1	58x38x4	1,000,000		58x38x4	1,000,000	3	Coke	Eng. Rec.,	40,603
Barrhead, Scot.	480,000	4	100x18x7		8	55x54x4		1½	Clinker	Eng. Rec.,	40,215
Champaign, Ill.	300,000	1	37x16x5	22,200						Eng. News,	42,111
Marion, Ia.	150,000			150,000	4	125x125	150,000		Sand		
Chicago Golf and—	950	1	12x12x3	3,240					Coke		
Polo Club	6,000	1		6,000			500,000		Coke		
Exeter, Eng.	50,000	1	68x18x9	53,800	5		660,000		Coke		
Verona,	40,000	1	18x50x10		4	14x14x4	2,000,000		Coke		
London, Eng.					1	22.5x10.7x6	1,665,000				

In considering these examples we are limited in our understanding by not knowing just what is the object sought to be accomplished. In some cases it is sufficient that the purification as controlled in the bacteria tanks or beds be carried only to such a point as will render the effluent unobjectionable to sight or smell, while in other cases it may be necessary to control the purification of the sewage until it can be discharged almost directly into the source of a public water supply, and herein lies the great applicability and flexibility of the process,—the sewage can be prepared, and that without offense, for the completion of the purification by dilution or irrigation, or the process can be controlled and the sewage kept within bounds until the final effluent from a series of bacteria beds can be discharged free of every possible contamination objectionable to the human system.

In the arid or semi-arid sections of the country the water contained in the sewage, aside from any manurial value of the organic contents, has a very great value for irrigation purposes, a value that may often be saved by some simple treatment. The sewage flow of Los Angeles equals about 700-800 miners' inches, and a small part of this now sells for irrigating purposes.

The wisdom of the City Council has decreed that sewage shall not be used for the irrigation of certain crops because it is feared that onions, strawberries, tomatoes, radishes and celery may transfer raw sewage from the fields to our mouths. There is some such danger if the irrigation is improperly or carelessly done and the sewage has not first been properly and sufficiently purified. If the crude sewage were first subjected to the hydrolytic action of the anaerobic bacteria in a septic tank and then to the nitrifying action of the aerobic forms in properly constructed bacteria

beds, the effluent could be most safely used for the irrigation of any and all crops or vegetables, and the manurial values being still retained in the purified effluent, the value of the sewage for irrigation would be materially greater than the value of clear water. It would be very interesting to compare the slight cost of so altering the present sewerage system of Los Angeles as to incorporate a septic tank, a part of which can be the sewers themselves, and a deep coke bacteria bed, with the cost of the present outfall sewer and the large outlay which must be put upon it immediately to rescue it from destruction; and also to contrast the annual cost of maintaining a system that sold 700 to 800 miners' inches of purified sewage with the present system of paying a big price to throw away the greater portion of the most valuable property the city possesses —the irrigation water supply which flows in her sewers.

Properly purified by these inexpensive methods described, the sewage of Los Angeles should yield a handsome revenue—greater than the revenue derived from the sale of river water in the days when it was mostly used for irrigation directly from the stream.

BIBLIOGRAPHY.

Engineering News, frequent notes, papers and illustrated articles.

Engineering Record, frequent notes, papers and illustrated articles.

"Inland Sewage Disposal." C. P. Bassett, Trans. A. S. C. E. XXV, 129.

"Self-Purification of Flowing Streams." C. G. Currier, Trans. A. S. C. E. XXIV, 21.

"Lectures on Bacterial Processes." S. Rideal, Jour. Soc. Arts, London.

"The Bacterial Treatment of Crude Sewage." Clowes & Houston. Two reports to London County Council.

"Manual of Bacteriology." Sternberg.

"Applied Bacteriology." Pearmain & Moore.

"Purification of Sewage and Water." W. J. Dibdin.

"Sewage Disposal in the United States." Rafter & Baker.

Reports of Massachusetts State Board of Health.

Report to Director of Public Improvements, City of Columbus, Ohio. Julian Griggs and J. W. Alvord.

"Sewage Treatment and Sludge Disposal." W. S. Crump.

"The Cesspool." L. P. Kinnicutt, Municipal Engineering, XIX, 99.

REPORT ON SEWAGE DISPOSAL

—FOR THE—

PACIFIC BRANCH, NATIONAL HOME FOR DISABLED VOLUNTEER SOLDIERS.

NEAR SANTA MONICA, CAL.

—BY—

JAMES D. SCHUYLER,
Consulting Hydraulic Engineer.

LOS ANGELES, CAL., June 14th, 1899.

Gen. O. H. La Grange,
Governor, N. H. D. V. S.,
Soldiers' Home, Cal.:

Dear Sir:—

The proposition made to the Management of the Soldiers' Home by the City Council of Santa Monica to permit you to connect the sewerage system of the Home with the outfall sewer recently constructed by the City of Santa Monica for discharging the city sewage into the ocean, has brought the question of the most expedient means to adopt for a permanent disposal of the sewage of the Home to a direct issue. Before deciding to accept or reject this proposition, Major Wm. H. Bonsall, Local Manager, placed the matter in my hands to make a thorough study of the entire situation and report upon all feasible methods available for the disposal of the sewage, with such recommendations as in my judgment seemed most expedient. In obedience to this trust I began the investigation on the 15th ult., and have made the necessary surveys and examinations since that date by which the data have been collected that enable me to prepare the following report, respectfully submitted for your consideration:

The proposition of the City Council of Santa Monica is set forth in the form of a resolution, No 291, passed March 21st, 1899, and embodies the following provisions:

The Home to build a sewage reservoir of 100,000 gallons capacity on the Home grounds, to be used as a flushing tank for the main outfall sewer.

The outfall sewer to be constructed by the Home from this reservoir to a point on Railroad avenue, midway between Tenth and Eleventh streets, a distance of 17,000 feet, to be not less than 10 inches in diameter.

Of this distance 2,600 feet are within the city limits of Santa Monica, which portion of the sewer must be deeded to the City immediately after completion. In consideration of this transfer and for the further consideration of $800.00 to be paid annually to the City, the Home would be permitted to discharge its sewage through the City system into the ocean. This privilege, however, would be subject to abrogation by either party on giving 18 months' notice of intention.

I examined the plans of the Santa Monica system in the City Engineer's office, and the constructed works in the City, sufficiently to satisfy myself that the capacity of the system is considerably greater than the present or probable future requirements of the town for many years to come, and that therefore the addition of the sewage from the Home would not over-tax the main outfall sewer. From the point where the proposed connection would be made the sewer is 12 inches in diameter for 2,000 feet, with a capacity of 1,300,000 gallons daily when half full; then follows 1,600 feet of 14-inch pipe on 2 per cent grade; then 6,753 feet of 20-inch on a minimum grade; and thence it is 24-inch to the end. The 20-inch pipe has a capacity of 2,500,000 gallons daily, and the 24-inch 4,600,000 gallons per 24 hours, running half full. At the crossing of Ocean avenue, where I examined the sewer, the depth of flow was but two and a half inches in the bottom of the pipe, indicating that the system is so little used as yet that it is greatly in need of a flushing head to drive out the accumulation of sewage below high-tide level.

The volume of sewage from the Soldiers' Home, applied in 100,000-gallon doses as proposed, would be precisely what is required by the City of Santa Monica to operate their system successfully, and the advantage of such a flushing would be so decidedly in the favor of the City that the annual payment suggested should

properly be reversed, and accrue to the Home rather than be a tax upon the Home. In other words, the proposition appears to me to be one which would only be acceptable to the Home as a *dernier ressort*. If there were no other effective and advantageous ways of disposing of the sewage of the Home the suggested plan would be one to be seriously entertained, although if discharge to the ocean is seriously considered at all, my preference would be decidedly in favor of an independent outfall sewer to be owned and operated exclusively by the Home, and not be subject to the caprice of the officials who may in future be selected to govern the destinies of Santa Monica, and who would have power to exclude the Home from enjoying the use of the City's main sewer, or even of that portion that had been built by the Home within the limits of the City, at a cost of some $2,400.

The estimate of cost of the proposed connection with the Santa Monica sewer prepared by Capt. E. J. Rising, Quartermaster of the Home, was $16,000, which covered the cost of the proposed reservoir and the necessary sewer pipe, manholes, etc., from this reservoir to the point of junction. It did not include, however, the sewer pipes required to be laid to connect all the Home sewers so as to discharge into the reservoir, which I find would need 2,350 feet of 6-inch pipe, and 1,550 feet of 8-inch pipe, the cost of which would be about $1,200. Captain Rising's estimate coincides with a bona fide bid for the work by a responsible contractor, and as far as it goes it may be accepted as sufficient with the addition of $1,200 for connections in the Home Grounds and a further addition for right of way and engineering, for which two items it would be safe to add another $2,800, making the total cost of this connection $20,000. In the matter of right of way the City of Santa Monica does not propose to provide the same, although the Council, in its proposition offers

its "best power and influence" to obtain the right of way for the Home. This "power and influence" may possibly not be sufficiently powerful to obtain the necessary rights free of cost to the Home, and therefore to cover all contingencies, it would be best to increase the estimate as suggested.

If the proposed reservoir is to act as the Santa Monica people desire it to act, in flushing out their sewer, it should discharge its contents of 100,000 gallons within a period not longer than one hour. At this rate, however, the capacity of the line would be overtaxed, and there would be danger of accumulating so much head on parts of the line as to either burst the pipe or overflow the manholes, and create a public nuisance. The discharge from the reservoir would have to be made with great care to avoid this result, and the gate would have to be raised just sufficiently to fill the sewer, and no more. This, I anticipate, would lead to much annoyance, and require so much special attention as to become a burden to the Home Management. It could never be neglected, or the reservoir might overflow. If the discharge were to be made automatic by a siphon, the rate of discharge would still be likely to be excessive, without a fine adjustment of the mechanism, which, with sewage is more difficult to attain than with clear water. If the sewage were allowed to flow without the proposed storage, as it comes from the Home, no reservoir would be needed, but this would not suit the purposes of the Santa Monicans, or comply with their proposition, and if the flow were to come to them in that way and not as a flushing head they would be likely to desire to rescind the contract or take action to compel such attention to the flushing as would annoy the Home Management.

Furthermore, the storage reservoir would be a greater source of nuisance and complaint from the

neighboring population than anything of which they have heretofore complained. It would accumulate the solid matter of each day's flow, which would cling to the bottom and sides and be difficult of removal without thorough washing and cleaning daily. The site selected for the reservoir is quite near the town of Sawtelle, and the odor arising from it would be sure to cause complaint. To wash it out daily would require additional labor, and a further expenditure of water, which the Home can ill afford to spare.

The volume of sewage discharged from the Home, as determined on May 27th, by careful measurements over well constructed weirs at each of the sewer outlets, was found to be as follows:

Kitchen sewer	12,782	gallons per 24 hours
Main Barracks sewer	60,959	" " " "
Hospital sewer	27,859	" " " "
Small sewer	3,400	" " " "
Total	105,000	" " " "

This is believed to be about the minimum flow, as the laundry was not in operation on that day. The volume of discharge from the laundry was ascertained approximately from the number of times the washing machines are filled, and computed at 7,000 gallons per day of eight hours. The laundry is now operated three and one-half days each week. The entire weekly flow may therefore be estimated at 759,500 gallons, or an average of 108,500 gallons daily. This may at times reach a considerably higher amount, possibly 120,000 gallons daily, and with the growth of the Institution it would be safe to provide for as much as 150,000 gallons per 24 hours. When this volume is reached the 100,000-gallon reservoir would have to be emptied every sixteen hours, and require more attention. Of course, it would be possible to plan a reservoir which would be emptied automatically at more

frequent intervals, but this is not the suggested plan, and the expense would be greater.

Considering all the conditions of the proposition made by Santa Monica, and the complications to which it may lead, I do not hesitate to advise that it be rejected.

Independent Ocean Outfall.

If any plan were to be entertained for discharging the sewage into the ocean either one of two routes for an outfall line may be selected. The shorter one, following a contour grade line from the Home to the Northwest corner of Santa Monica, and thence along the Northerly boundary of the City, to the ocean, would require a total length of 25,600 feet of pipe, including 1,200 feet of cast-iron outfall in the ocean, and cost approximately $50,000. The other via Ballona Slough, reaching the ocean about one-half mile South of the Santa Monica outlet, would require 33,300 feet of pipe, and cost approximately $62,000, including cast-iron pipe laid on the floor of the ocean about 1,200 feet out from shore, with the necessary wharf for maintaining it. By the Northerly route the pipe would reach the shore where the bluffs are high, be suspended over the railway tracks, and rest on top of the wharf, discharging freely into the ocean above tide level at the end of the wharf. By the Southerly route the low elevation of the shore would probaly compel the pipe to be laid on the ocean bed.

These alternative plans for carrying the sewage of the Home to the ocean have been considered at the request of Major Bonsall, and are briefly mentioned, for purposes of comparison in the matter of cost, with other plans of sewage disposal to be discussed later on in this report. Both of them are practicable, and feasible, but I do not regard either of them as offering the best solution of the problem, and therefore cannot

recommend their serious consideration, not only because of the great expense involved, but for the reason that it would deprive the Home of a very considerable portion of its present irrigation supply.

Disposal by Irrigation.

Since the establishment of the Home, nearly twelve years ago, the sewage has been used for irrigating the vegetable gardens, the alfalfa field and the orchards of the Home Grounds. This has been accomplished without offense to the population of the Home, possibly due to the fact that the prevailing winds are from the ocean and carry any effluvia arising from the fields away from the buildings. Complaints have come, however, from the occupants of two or three dwellings on adjacent lands to the East of the Home Grounds, of offensive odors, which at certain times in the hottest weather are said to be quite unbearable, and threats of injunction have been made by these neighbors, to prevent a continuance of the use of sewage for irrigation. The inhabitants of the village of Sawtelle, adjoining the Home on the South, are also beginning to fear these odors, and are apprehensive of a possible contamination of their water supply, which is derived from wells sunk on the town site, by percolation from the sewage-irrigated fields, which lie at a higher level, and are a part of the sloping plain on which the village is built. The depth of the wells in the town is from 60 to 180 feet, and the level of the plane of saturation is from 45 to 70 feet below the surface. The valley lands, which are irrigated with sewage, have a general slope of about 2 per cent, and are composed of fine alluvial loam, intermixed with streaks of fine gravel, in irregular channels, which cannot be traced with any special continuity through the land, although following generally parallel with the little surface water-courses. Here and there the gravel is in patches on the surface,

and excavations show that it occurs in layers alternatign with the soil. The general slope of the fields, however, is toward a main water-course to the Eastward, leading away from the direction of the village. I regard it as practically certain that no amount of water applied to the surface in irigating these fields could possibly reach the wells of the town at their great depth, but would be carried away to one side, while the very small amount of water actually applied would be absorbed in plant growth, evaporated from the surface soil, or retained in the soil by capillarity, aside from the fact that all germs of disease or contamination carried by the sewage would be oxidized and destroyed by the natural processes of nature long before reaching the depth or distance which would have to be traversed to permit them to contaminate the well waters of Sawtelle. In fact, the only way the water of these wells could be affected would be by conducting a sewer pipe to each of them and allowing the raw sewage to mingle with the water. The land directly over or around them might be irrigated intermittently, in moderate amount, without danger of contamination, while it is as certain as any other well-established fact that under existing conditions no impurity can come to these wells from the sewage irrigation of the Home.

On the great sewage farm of Berlin, Germany, for example, the entire water supply of the people living on the farm, (numbering 7,900 in 1890), is derived from wells, dug in the midst of irrigated fields, and the health of the inhabitants of the farm is so excellent that it has been chosen as the site for four Homes for Convalescents. The sewage farm is in fact a health resort, rather than a breeding place for disease. This experience is confirmed in all parts of the world where sewage irrigation is scientifically practiced. The danger of impairing the water supply of Sawtelle by continuing sewage irrigation at the Home may therefore be

dismissed from consideration as absolutelv groundless and beyond all possibility of ever occurring, unless as I say, the raw sewage is brought directly to the wells and mingled with the water.

From my examination of the methods of handling the sewage in vogue at the Home I can readily understand why complaints of bad odors should have arisen. I found quite a number of foul-smelling ditches where sewage had been allowed to flow so long that the land was supersaturated beyond its ability to absorb further moisture, and the solid matter was putrefying and festering in the sun; shallow cesspools where matter had accumulated and was decaying, and various open stand pipes along the lines of the sewers filled with offensive feces. A number of the garden beds were also waterlogged with excessive application of sewage without cultivation, and solid matter was decaying on the surface of such over-taxed and over-soaked areas. The sum of all these neglected spots, offensive to the eye and the nostrils, was sufficient, when conditions became most favorable, to create a nuisance to those living to the leeward, and I have no doubt the complaints have not been altogether from imaginary causes. I doubt, however, if the health of the neighborhood has been in the slightest degree impaired, but a bad smell is a nuisance, and it is this fault which must be corrected. It is the duty of every community to care for its waste products and purify or dispose of its sewage in such manner as to render it inoffensive to any one residing in its vicinity.

Methods of Sewage Purification.

As a concrete result of the experience gained in the Eastern States and in England, France and Germany, the disposal of sewage has resolved itself to three general methods, which are known as—

1. Broad irrigation,

2. Intermittent downward filtration,
3. Chemical precipitation,

and named in the order of accepted preference. A combination of any two of these methods is frequently employed to effect such a degree of purification as will render the effluent admissible into streams from which domestic water supply is derived. The late Colonel Geo. E. Waring, the eminent Sanitary Engineer, writes:

> "To accomplish this natural purification, (by which the water of the foulest sewer can be made as pure as that of the mountain brook), it is only necessary to bring the sewage into contact with light, well-aerated soil.
>
> "The reducing bacteria always abound in the sewage itself, in the surface soil and in the air, and oxygen, the only other essential, is freely supplied by the atmosphere. When sewage is spread over a natural surface, it is important that it be applied in thin sheets and intermittently, so that every particle of the liquid and of the soil may come in contact with the air. This is the process known as 'Broad Irrigation.' Where abundant land is available it is the system par excellence for sewage treatment. Under good management one acre will purify the wastes of from five hundred to one thousand persons."

The concensus of opinion of all the leading Sanitarians of England is unanimous to the effect that the preferable mode of purifying town sewage is by application to land. Mr. Geo. W. Rafter, M. Am. Soc. C. E., one of the leading Sanitary Engineers of the United States, says, after reviewing the numerous authorities on the subject in extenso, (Water Suuply and Irrigation Papers of the U. S. Geological Survey, No. 3, p. 48):

> "So overwhelming is this evidence that we must, in the future, consider this part of the subject as what the lawyers call *res adjudicata*, a proposition absolutely settled and no longer to be called into question."

On page 29 of the same publication he says:

> "As a problem of efficient purification, therefore, the superior efficacy of the land treatments may be conceded without further discussion."

Again he writes:

> "Formerly it was considered important to select a sewage farm with reference to the surrounding inhabitation, because there was a prejudice against such farms on account of the assumed liability of effluvium nuisance. This objection has much less weight now than it formerly had, because experience has fully demonstrated that with proper management a sewage farm is no more objectionable on account of bad smells than any other mode of farming. We may conclude, therefore, in the light of present experience, that an objection to sewage farms on account of serious effluvium nuisance is not well founded."

The influence of sewage-irrigation upon public health is discussed in Parkes' "Manual of Practical Hygiene," (1884):

> "That sewage farms, *if too near to houses and if not carefully conducted,* may give off disagreeable effluvia is certain; but it is also clear that on some farms this is very trifling, and that when the sewer-water gets on the land it soon ceases. It is denied that more nuisance is created than by any other method of using manure. . . The evidence of Edinburgh, Croydon, Aldershot, Rugby, Rumford and the Sussex Lunatic Asylum is very strong against any influence in the production of typhoid or dysentery by sewage-farm effluvia."
>
> "It has been proven by very exact and interesting experiments of Haegeli and Buchner," (says Dr. Wm. H. Welch, Prof. of Pathology, Johns Hopkins University, Baltimore) "that bacteria are never lifted by a current of air from the surface of fluids or from moist surfaces in general. One could remain in a room containing any quantity of cholera stools, swarming with cholera bacilli, and there would be no danger of infection with cholera through the air. Bacteria are conveyed into the air only when they are in a dry condition, and the cholera organism is quickly destroyed by drying."

Substantially the same reasoning is applied to the germs of typhoid fever and other enteric diseases.

Without multiplying authorities on this subject, I think you may be assured of these facts:

1st. That the process of disposing of your sewage by broad surface irrigation, when properly applied, is the most effective means of purifying and rendering it innocuous.

2nd. That while this process may be accompanied by slight odors, these can be so eliminated as to be unnoticeable a few hundred feet distant.

3rd. That there is no danger to health in these odors, nor any foundation to fear the spread of disease germs from the irrigated fields by wind currents passing over them.

4th. That there is no danger of your sewage-irrigated fields ever becoming over-loaded or "sewage sick," if the sewage is properly spread over even a fourth or fifth part of the area readily available for its use, and the land will always be benefited by its application.

Furthermore, the value of the sewage for irrigation at the Home can not only be rated in the direct proportion which it bears to the entire water supply, but for its value as a fertilizer of the irrigated fields. The present water supply of 500,000 gallons daily costs $10,000 per annum. Approximately one-fourth of this volume passes off in sewage. If the sewage were to be carried away to the sea an equal volume of clear water would need to be purchased to replace the loss, as the successful growth of vegetables and fruit at the Home demands constant irrigation to maintain it. This would represent a money value of $2,500 per annum.

The manurial value is still higher. On the basis of our average flow of 108,500 gallons daily I estimate

that the sewage flow for one year contains the following elements of plant food:

Nitrogen	32,900 lbs.	worth	17c per lb.	$5,493.00
Phosphoric acid....	9,250 "	"	7c " "	647.50
Potash	6,200 "	"	5c " "	310.00
			Total	$6,450.50

The values above quoted are the market rates for these minerals in New York. If to this be added the value of the water, and the proposed tax of $800 per annum which the City of Santa Monica desires you to pay for carrying your sewage it is apparent, from these figures, that an acceptance of the Santa Monica proposition would virtually mean an expenditure of $20,000 for the privilege of throwing away nearly $10,000 of value per annum. Your gardening may not be so conducted as to enable you to realize the full value represented by these startling figures, although from the great yield which I have seen produced on the land I have no doubt you enjoy a very considerable portion of this amount. I am certain that the fertility of your fields would be greatly diminished by discontinuing the use of the sewage.

Special Advantages of California for Sewage Disposal by Irrigation.

The climatic conditions of California, and particularly the Southern portion of the state, are specially favorable for sewage irrigation, because of the light rainfall, the large proportion of clear, sunny days, and the general dryness of the air, which renders irrigation necessary and desirable for the production of crops throughout the year. In the Eastern States and in Europe, on the contrary, where the ground freezes and all growth ceases in winter, irrigation at that season becomes more difficult, and it is necessary to resort to

artificially prepared filter beds for the treatment of sewage.

The soil of the Soldiers' Home gardens is also favorable for successful disposal of sewage, while the very large area of the land suitable to irrigation renders it easy to care for the limited volume of sewage in the best possible way. I find that the area at present irrigated, below the outlets of the sewers, is approximately 116 acres, distributed as follows:

Orchard, irrigated from kitchen sewer and partly from main barracks sewer	32.2 acres
Garden, irrigated from kitchen sewer	10.4 acres
Vegetable garden, between main barracks sewer outlet and boulevard	10.7 acres
Vegetable garden, between boulevard and hospital sewer outlet	12.9 acres
Corn field, irrigated from hospital, kitchen and barracks sewer	30.2 acres
Corn field, irrigated from smallest sewer	7.8 acres
Alfalfa field, irrigated from laundry sewer	11.8 acres
Total	116.0 acres

In addition to this there are 20 acres, now in grain, which could be watered by gravity from the main barracks and kitchen sewers. When it is considered that the volume of sewage produced might, if necessary, be effectively disposed of on 10 acres at the rate of application given to the sewage farms of Paris, France, where the entire sewage of the City is thus being used in irrigation, the area available at the Home is seen to be more than ample. In fact very much more clear water than sewage is used for irrigation at the Home to grow the crops that are planted.

The Composition of Sewage.

In sewage of average degree of dilution it is found that 998 parts out of 1,000 are pure water, one part consists of mineral matter of a harmless nature, salt,

etc., and the remaining one part is dead organic matter, which alone has the power of becoming offensive. It is well understood that the decay or decomposition of animal and vegetable tissue is due to the agency of micro-organisms, called bacteria, microbes or germs. These exist naturally in all sewage in enormous quantities, ranging from a few hundred thousand to several millions per cubic centimeter, (one-sixteenth of a cubic inch). They belong to a vast number of species and are capable of working the most diverse effects upon the materials in which they live. The study of the work of these organisms by such eminent bacteriologists as Pasteur, Frankland, Warington, Winogradsky, and the biologists of the State Board of Health of Massachusetts, has, within the past ten to fifteen years, added to the scientific knowledge of the world a vast chapter of information which reads like a romance and completely upsets all previously entertained theories of the chemical resolution of organic matter into mineral. It is known that conditions which favor one kind of bacteria are deadly to certain other kinds. The species which convert ammonia into nitrous and nitric acids, and which are most useful in the safe destruction of sewage, require oxygen for their activity and life, and are designated, therefore, as aerobic bacteria, while those which produce putrefaction and decay cannot exist actively where much air is present, and require the absence of light and air to do their most effective work. Hence they are called anaerobic bacteria. Both of these species of microbes when properly controlled are the friends of man and the modern processes of sewage disposal are those which intelligently make use of these microscopic organisms for the reduction of the wastes of the world to innocuous mineral matter. Temperature is an important element in promoting the work of these organisms, as they are comparatively inactive in temperatures

below 40 deg. or above 120 deg. Fahrenheit. The aerobic bacteria are those at work in the soil, when the sewage is applied to the surface, and they exist in greater numbers on the surface, or a few inches below than at greater depths, as they can there get the greatest amount of oxygen. One species convert the organic matter into nitrous acid, and another species transform the nitrous into nitric acid, which combines with mineral bases to produce mineral nitrates, and the process is called nitrification. In this form it becomes food for plants, and is thus again reconverted into organic matter, and so the eternal round of Nature's economy goes on. In order that these bacteria may be periodically supplied with oxygen, and continue the work of nitrification it is essential that the application of sewage to the soil be made intermittently, to permit each dose to be wholly nitrified before the next is applied. The stirring of the soil after each irrigation assists in the work, as it reopens the pores and admits air to the organisms at lower depths below the surface. If the land is overdosed, and sewage is permitted to flow in any one place too long a time, the aerobic bacteria are destroyed or checked in their active multiplication, and the anaerobic bacteria have to take up the work. But their action is to produce offensive smells, and for this reason stagnant pools give rise to unpleasant odors. The secret then of successful sewage irrigation is to keep the sewage in motion, apply it in small doses to the most porous land available, at intervals of not less than three or four days, keep this land well stirred between irrigations, and so prevent the bacteria of putrefaction from taking an active interest in the process of having a hand in it at all. In short the organic matter should be burned by oxidation and converted into nitrates by the aid of the microbes that are ready and willing to do the work if given a chance. When the process is finally over, and the

organic matter has been resolved into mineral again the bacteria die from inanition, and the effluent water drained out from beneath the irrigated fields, if any, or from sewage filter beds, is pure, and comparatively free from bacteria. In fact, the effluent is often much freer of microbes than the waters of many springs and wells which are regarded as pure.

The process called "intermittent downward filtration" is merely an artificial concentration of the process which goes on in broad irrigation. Filter beds are prepared with materials which will admit air freely through them when periodically drained out. They are prepared with underdrains, are filled with coke, or burnt ballast, gravel and sand. The coke is preferred by many authorities because it is of itself porous, and presents a greater surface. The bacteria colonize in vast numbers over the surface of the gravel, sand or coke particles, in thin films, and porosity of the filter is desirable because the nitrifying organisms are thus well supplied with air. For complete nitrification, the sewage must be kept in contact with the organisms a short space of time, and then drained out slowly. Such filters, or bacteria beds as they are sometimes called, are used where sufficient land is not obtainable for broad irrigation, or as a method of treatment in cold countries in winter, as an adjunct to the sewage farm. They cost from $5,000 to $9,000 per acre, and are capable of purifying from 50,000 to 100,000 gallons of sewage per acre daily on an average, applied at intervals of three or four days.

A greater rate of filtration, or what is the same thing, a smaller filter for a given unit volume of sewage will effect a lesser degree of purification, and where the effluent is to be used for irrigation a very moderate amount of clarifying will answer every purpose. A sufficient number of them are provided to give the necessary capacity and intermittency of use to each,

dependent upon the degree of purity desired. Frequently the surface of the beds is cultivated, and crops of corn or other produce raised upon them during the growing season. A bed of this sort, if built at the Home, divided into four compartments, and arranged with means of distributing the sewage, to each in turn, would serve to concentrate all the solid matter of the sewage at one point, where it would be chiefly neutralized without creating offensive odors. The paper and other light matter can be raked in piles and burned, or it may be worked into the soil by cultivation. The surface of such a coarse-grain filter can be used for growing certain crops as advantageously as an ordinary soil. It would remove all the unsightliness of scattered sewage solids over the fields, and the sludge would become so quickly oxidized as to be comparatively free from odor. The effluent stream flowing from beneath the filter would be almost clear, and undistinguishable from hydrant water, although loaded with fertilizing nitrites.

I append a sketch of this filter, which I have estimated to cost as follows:

Excavation	5,680	cubic yards	at 20c	$1,136.00
Clay lining	2,080	" "	" 50c	1,040.00
Gravel, screened and placed	3,600	" "	" $1	3,600.00
2-inch drain tile	2,000	feet	" 3c	60.00
3-inch drain tile	2,000	"	" 3½c	70.00
6-inch drain tile	700	"	" 10c	70.00
6-inch vitrified pipe	600	"	" 17c	102.00
8-inch vitrified pipe	400	"	" 22c	88.00
Sluice gates	16	"	" $3	48.00
Incidentals				276.00
			Total	$6,500.00

A filter of smaller size and cost would probably answer every purpose, although the plan is made for one large enough to render the sewage practically potable.

If this were located in the field below the present terminus of the Hospital sewer, and all the sewage brought to this point in pipes, there would need to be laid about 2,700 feet of 6-inch sewer to make all connections, the cost of which would be about $900. The entire cost of the improvement would therefore foot up $7,400. The cost of operation would be practically nil, as the garden force would be able to attend to the filter without appreciable extra labor.

OXIDATION OF SEWAGE BY FORCED AERATION.

In 1894, Colonel Geo. E. Waring invented a process of destruction of sewage by forced aeration, supplying a draft of air by means of fans or blowers to filter beds, constructed and operated similarly to the ones above described, except that they are of much smaller size, and arranged as a series of concrete tanks. This process is in operation at four places in the United States, and the patents upon it are controlled by D. A. Tompkins & Co., of Charlotte, N. C., who estimate that a plant to clarify 150,000 gallons daily will cost $4,000 to $6,000, and the operating expense will be covered by the cost of running a fan driven by an eight-horse dynamo, and a man to look after the valves about four times a day. They write that such a plant will remove absolutely all smell and taste, leaving the effluent a slightly milky color, and fully charged with all the mineral fertilizers contained in the sewage, putting it in a most desirable form for irrigation. Personally I know nothing of this method of treatment, but understand that it merely does the work of the coarse-grained filter, at somewhat greater operating expense. The principle is the same, air being blown through the gravel of the filter from the bottom after the sewage is drained out, to promote the action of the nitrifying organisms more rapidly and enable a smaller filter to do the work. The entire space occupied by the con-

crete or brick tanks would be 60 to 70 feet square, for a 150,000-gallon plant.

Chemical Precipitation.

Either of the processes above described are preferable to the chemical precipitation of the sewage, for which the plant and buildings would cost in the neighborhood of $10,000, and the operating expense would be $8.00 to $10.00 per day.

Mr. John W. Alvord, M. Am. Soc. C. E., the distinguished sanitary specialist of Chicago, writes to the author under date of May 29th, 1899, as follows:

> "In the light of our recent success with reduction (septic) tanks and bacteria beds, I certainly regard chemical treatment of sewage as out of date, especially in the vicinity of soils or conditions of climate where broad irrigation is practicable, as in Southern California."

Septic Tank Treatment of Sewage.

One of the most interesting of the newer processes devised for the treatment of sewage is known as the septic or reduction tank system. This was first tried on a large scale in Exeter, England, where it has been in use about three years.

While the system is regarded as still in the experimental stage it has attracted great attention and interest among the sanitary engineers of the world, who are inclined to regard it as offering great promise. The process consists of conducting the sewage to a long tank, made air-tight and dark, through which it passes very slowly, emerging at the far end in liquid form. In this tank the work of reduction is done by anaerobic bacteria, the solids in suspension are retained and changed to gas and liquid, while the mineral matter is precipitated to the bottom as an inert, inoffensive ash. The Exeter tank treated 65,000 gallons daily for 22

months without giving any sign of requiring the removal of the deposit. It is located in a thickly settled part of the city and gives no offense. The tank forms marsh gas, and nitrogen gas, but shows no trace of sulphuretted hydrogen. The gas is innocuous and could only be detected by applying a light. It has been used for months for lighting the works and the public baths in the vicinity, using incandescent burners. The flame is odorless and almost without color. The tank is 64 feet 10 inches long, 18 feet wide, and 7 feet to 7 feet 9 inches deep, having a capacity of 65,000 gallons. For further purification the effluent from the tank is passed through filter beds, where nitrifying organisms complete the work. The advantage of this process seems to be in the ease with which all the troublesome solids or sludge is disposed of. Everything enters at one end, while at the other there issues a continuous stream of fluid, with but slight flocculent particles of dark color, distributed through it.

Similar reduction tanks have been constructed near Chicago within the past year or two by Mr. J. W Alvord, in connection with coarse-grain filters, with satisfactory results thus far.

At Champaign, Ill., a septic tank of practically the same design was built for the treatment of about 300,000 gallons of sewage daily, and is reported to work satisfactorily. It was planned and constructed by A. N. Talbot, M. Am. Soc. C. E., Professor of Sanitary Engineering at the University of Illinois, and was made 45 feet long, 16 feet wide, with a central division wall, forming two tanks in one, and carries five feet depth of sewage. Partitions or baffle boards reach down into the sewage from the top to within two to two and one-half feet of the bottom, which hold back the floating crust of excrement (that forms to the depth of several inches on the surface,) from moving toward the outlet. The fluids from the tank are permitted to

escape through a slotted pipe, placed some depth below the surface, the pipe discharging outside over a weir that controls the level of the sewage inside within a range of less than two inches. The deposit on the bottom of the tank, which mav be removed once every year or two, is described by Professor Talbot in a private letter to the author as—

> "a thick, black silt-like material containing about 60 per cent water, 35 per cent inorganic matter, and 5 per cent organic matter. The inorganic compounds are so stable that after removal they do not seem to give off any particular odor, although at the time of cleaning out the tank and around the pit in which the sludge is discharged, there is an odor similar to that of dirty water, but I do not think it could be noticed 300 feet away. At other times there is no perceptible odor in the neighborhood of the tank, though it must be borne in mind that the effluent discharges into a stream under water. By putting one's nose close to the end of the effluent sewer where the air current comes out of the sewer, a slightly musty, swamp-like odor may be detected. I have had a bottle of the effluent in my office for five months and have not at any time found any odor which indicated a decomposition. There has been a slight growth of greenish algae in the bottle similar to that which is found about horse-troughs supplied with good well water. A rough determination of the ordinary bacterial content showed that 90 per cent of the bacteria of the sewage were taken out. . The sludge taken care of seems to amount to about four cubic feet of dry matter per million gallons of sewage treated, a quantity not over one-fifth of that required to be discharged by the chemical process."

Sketch No. 2, attached herewith, shows a design of a septic tank for the treatment of the sewage of the Home, which appears to me of proper proportions. I estimate the cost as follows:

Excavation, 450 cu. yds. at 20c	$ 90.00
Concrete walls and bottom, 3,000 cu. ft. at 30c . .	900.00
Concrete and iron cover, 1,000 sq. ft. at 50c	500.00
Pipe, weir, valves, etc	310.00
Total	$1,800.00
Pipe for connecting all the main sewers to the tank	900.00
Total cost	$2,800.00

While the evidence obtainable regarding the efficiency of the septic tank system is all favorable to its success, and its use is rapidly extending, it must be borne in mind that, as before remarked, it is still regarded as in the experimental stage. Its cheapness and apparent simplicity are all in its favor as compared with other systems, and I am inclined to recommend its trial notwithstanding a possible doubt of its effect in reducing the fertilizing value of the effluent sewage. Its action appears to be in the direction of removing the nitrates, which afford most of the desirable plant food, although the effluent from it would unquestionably be richer in fertilizing elements than clear water.

Summarizing the various plans of disposal discussed in this report, the estimates of cost appear as follows:

Ocean Outfall Plans:

Connection with Santa Monica sewer system	$20,000
Fixed charges of $800 per annum, capitalized at 5 per cent	16,000
Total	$36,000

(The cost of maintaining main sewer, attending to reservoir discharge, cleaning, etc., is neglected in making this comparison.)

Independent outfall by Northern route	$50,000
Independent outfall by Southern route	62,000

Disposal on Home Grounds:

Intermittent filtration in coarse-grain filters	7,400

Oxidation by forced aeration, first cost . .	$ 6,000	
Capitalization of operating expense at 5 per cent.	7,300	
		13,300
Chemical precipitation, first cost.	$10,000	
Capitalization of operating expense at 5 per cent.	58,400	
		68,400
Septic tank		2,800

Considering all the conditions, I make the following recommendations:

That the kitchen sewer be joined by a direct line from the tunnel to the present terminus of the main barracks sewer, and that at this point a septic tank be constructed at a cost not to exceed $2,800, including the pipe connections, to be used experimentally for the treatment of the portion of the sewage uniting at that points;

That the effluent from the tank be liberally diluted with fresh water and applied to the fields in irrigation;

That the importance of the proper care of the sewage be recognized by the appointment of a sewer inspector of more than ordinary intelligence, whose duty it shall be to see that the sewers are kept properly flushed, all the manholes kept clear of floating solids, and that all offensive places on the farm be eliminated;

That the distribution of the sewage shall be made intermittently, and that no portion of the soil be permitted to become "sewage sick" by over-dosing, and

That all the ditches be kept clean and the ground stirred and cultivated after each irrigation. By attention to these details there should never arise the slightest cause of complaint, and the sewage of the Home can be forever cared for on the Home Grounds, without the least danger of epidemics, offensive odors, or the contamination of the neighboring water supply.

The need of a careful patrol system was illustrated on the 6th inst., when I found the Hospital sewer

choked and overflowing at a manhole in the alfalfa field. This should never occur, or if it did occur the remedy should be promptly applied and the sewer inspector held responsible for the perfect condition of the system at all times. Other Departments of the Home are managed with military precision, and order and cleanliness are everywhere apparent. In this, one of the most important of all the economies of the Institution, there is an apparent lack of intelligent supervision and careful attention, which should be promptly reformed.

Trusting I have made my views clear on this subject, I beg to remain, Dear Sir,

Faithfully Yours,

JAMES D. SCHUYLER.
Consulting Hydraulic Engineer.